EFFECTS OF PRESCRIBED BURNING ON VEGETATION AND FUEL LOADING IN THREE EAST TEXAS STATE PARKS

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Abstract.—This study was conducted to evaluate the initial effectiveness of prescribed burning in the ecological restoration of forests within selected parks in east Texas. Twenty-four permanent plots were installed to monitor fuel loads, overstory, sapling, seedling, shrub and herbaceous layers within burn and control units of Mission Tejas, Tyler and Village Creek state parks. Measurements were taken during the summers of 1999 and 2000. Prescribed burning was conducted between these sampling periods in early spring 2000. Results indicated that the current applications of prescribed burning do not significantly influence vegetation or fuels. Sustained drought, prior management practices and imposed local burn bans reduced the window within which prescribed burns could be applied, and limited the effectiveness of the burns.

Historically, fire has played an important role in most terrestrial ecosystems. Fire has an influence in such ecosystem components as recycling of nutrients, regulating plant succession and wildlife habitat, maintaining biological diversity, reducing biomass, and controlling insect and disease populations (Mutch 1994).

When conducted properly, prescribed fire undoubtedly alters the composition and structure of the understory vegetation within forests. Several subclimax communities and endangered species of Texas are dependent on fire. For example, fire is an essential element in the restoration and management of longleaf pine (*Pinus palustris* Mill.) stands and pitcher plant (*Sarracenia alata* Wood) wetland ecosystems. These and other communities benefit from an active prescribed burning program (Reeves & Corbin 1985).

Prescribed burning is currently used as a management tool in several Texas state parks for the purposes of reducing forest fuels, improving wildlife habitat, altering the composition and structure of the understory vegetation and enhancing park appearances. This study was conducted to evaluate the initial effectiveness of prescribed burning in the ecological restoration of forests and consisted of monitoring pre- and post-burn vegetative characteristics and fuel loads at three Texas state parks. At Mission Tejas State Historical Park, Tyler State Park and Village Creek State Park, 24 plots, eight in each park, were monitored in the summers of 1999 and 2000 to determine short-term ecological effects of pre-scribed burning on vegetation and fuel loads.

METHODOLOGY

The three parks surveyed in this study were all part of the Pineywoods Region of Texas Parks and Wildlife Department's Parks and Historic Sites. Mission Tejas and Tyler State Parks had similar ecological characteristics. Typical overstory species within the burn units of these parks included shortleaf pine (*Pinus echinata* Mill.), loblolly pine (*Pinus taeda* L.), sweetgum (*Liquidambar styraciflua* L.), water oak (*Quercus nigra* L.), white oak (*Q. alba* L.), mockernut hickory (*Carya tomentosa* (Poir.) Nutt.), white ash (*Fraxinus americana* L.) and American holly (*Ilex opaca* Ait.). Common understory species included yaupon (*Ilex vomitoria* Ait.), flowering dogwood (*Cornus florida* L.), American beautyberry (*Callicarpa americana* L.), longleaf uniola (*Chasmanthium laxum* var. *sessiliflorum* (L.) Yates), panicums (*Panicum* sp.) and various sedges (Texas Parks and Wildlife 2000a; Texas Parks and Wildlife 2000b).

Average low temperatures in January range from 0 to 2°C, while July averages highs of 34 to 36°C. The first and last freezes typically occur around mid to late November and mid March to early April, respectively. Average rainfall exceeds 100 cm per year (Texas Parks and Wildlife 2000a; Texas Parks and Wildlife 2000b). Steep slopes abound in these parks, with elevation changes of 100 m within both parks (Texas Parks and Wildlife 2000a; Texas Parks and Wildlife 2000b; Robinson & Blair 1997). The historic fire return interval where these parks are located was 4 to 6 years. It is presently greater than 20 years (Jurney 2000) due to suppression, fragmentation and urbanization of the surrounding areas. Heavy fuel loads persist throughout the park due to decades of sporadic use of fire.

Unlike the others, Village Creek State Park included cypress swamps, bottomland wetlands and blackwater sloughs in the flood plain of the Neches River. The burn unit was once a longleaf/little bluestem (*Schizachyrium scoparium* (Michx.) Nash.) stand. Due to fire exclusion it was being overtaken by broadleaf trees, such as water tupelo (*Nyssa aquatica* L.), river birch (*Betula nigra* L.), water oak and redbay

(*Persea borbonia* (L.) Spreng.), in addition to the invasive Chinese tallowtree (*Sapium sebiferum* (L.) Roxb.). Common understory vegetative species included yaupon, flowering dogwood, American beautyberry, poison ivy (*Toxicodendron radicans* (L.) Kuntze), little bluestem, panicums and various sedges. The park's mean elevation was 7 m. January's average low temperature was 3°C, while July's average high was 34°C (Texas Parks and Wildlife 2000c). Historic fire return interval in the area was 1 to 3 years. Now it is greater than 20 years (Jurney 2000).

Methods for establishing plots, and sampling vegetation and fuel loads were as defined in the *National Park Service Western Region Fire Monitoring Handbook* (Western Region Prescribed and Natural Fire Monitoring Task Force 1992). Plot size and sampling locations varied for each monitoring variable. Consistent sample areas were used between plots for each variable. The entire 20 by 50 m rectangular plot was used for sampling overstory (Figure 1). Overstory trees were defined as all trees, living or dead, with dbh > 15 cm. Dbh (diameter at breast height) was defined as diameter outside bark at 1.4 m.

Saplings were defined as standing living or dead trees with dbh ≥ 2.5 cm and ≤ 15 cm. They were sampled only within Quarter 1. Seedlings were defined as those living trees with dbh < 2.5 cm. Seedlings were monitored only in the 5 by 10 m medial section of Quarter 1.

The point line-intercept method was used for sampling shrub and herbaceous layers. The point line-intercept transect ran along the Q4-Q1 50 m line delineating that outside long axis of the plot. Height of the tallest living or dead individual by species, and species from tallest to shortest intercepting the transect were recorded.

To obtain shrub density, the Q4-Q1 transect was widened to a belt 0.5 m wide. A stem count of shrub species within the belt was recorded. To measure density of herbaceous plants, a 1 m^2 frame was placed on the plot side of both outer 50 m transects every 10 meters. The total area sampled in each plot using this method was 10 m^2. Herbaceous species and number of stems were recorded.

Four transects extending 15.2 m in random directions from the centerline at the 10, 20, 30 and 40 m marks in each plot were used to measure fuel loads (Brown et al. 1982). One-, ten-, hundred- and

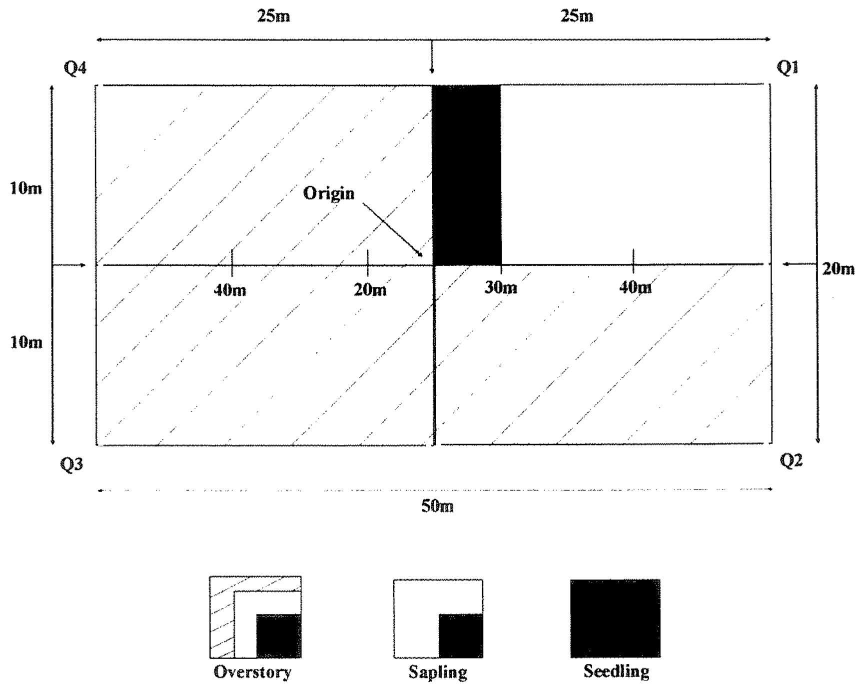

Figure 1. Sampling areas and transects for vegetation and fuel load monitoring (Western Region Prescribed and Natural Fire Monitoring Task Force 1992).

thousand-hour fuels were sampled along these transects. Depth of O_i and O_e (litter) horizons combined was also measured, as well as, depth of O_a (duff) horizon. Samples of O_i and O_e horizons combined were collected and dried to determine litter weight. All vegetative and fuel load monitoring techniques were repeated during the same time of the year 2000.

Texas Parks and Wildlife Department (TPWD) personnel produced the burn plans. Prescribed burns were conducted during late February to early March 2000 when weather and fuel moisture conditions allowed.

To estimate the intensity of each burn, four tiles with heat-sensitive paint were attached to the center t-post of each plot. One tile each was placed 15 cm below ground, at ground level, 30 cm and 61 cm above ground. Tiles were removed immediately after the burn. Analyses of the tiles allowed an estimate within 38°C of the fire temperature at plot origin.

County burn bans prohibited burning in the parks until they were temporarily lifted following rain episodes. Because of the necessity to wait until a rain event, fuels were wet and resulting burns were weak and spotty. Firelines were monitored for two hours after each burn was completed. Park staff was responsible for monitoring the burn unit after that time.

According to written burn plans (Sparks 1999a; Sparks 1999b; Robinson & Blair 1997), the primary objectives of the initial burns were to reintroduce the natural role of fire into the ecosystems and to reduce fuel loads. Other objectives mentioned included reducing risk of wildfire, increasing species richness and diversity, increasing wildlife habitat for numerous species, encouraging longleaf pine seedlings at Village Creek State Park and beginning the first stage in restoration. Cool season burns were recommended every two years to reduce fuels sufficiently for growing season burns. Following three cool season burn cycles, burns would be conducted once every three years during the early to mid-growing season to increase mortality in understory hardwood saplings.

Fuel loading (Mg ha^{-1}) was calculated using Excel software. *ANOVA* and paired *t*-tests were performed to test for significant differences in pre- and post-burn fuel loads and vegetation in SPSS Base 10.0 (SPSS Inc. 1999). Exploratory analysis was conducted on data in PC-ORD (McCune & Mefford 1999) using twinspan, Detrended Correspondence Analysis (DCA) and graphing the DCA. DCA was designed for ecological data sets. It is based on samples and species, and ordinates both simultaneously (McCune & Mefford 1999).

Paired *t*-tests were conducted in Excel on overstory and sapling vegetation to determine differences in standing dead vegetation before and after the burns. Morisita's index of similarities was conducted on seedling, shrub and herbaceous communities to determine differences in composition before and after the burns (Morisita 1959). Morisita's index was formulated as follows:

$$C_M = \frac{2\sum X_i Y_i}{(S_A + S_B) N_A N_B}$$

Where: X_i = Number of species i in community A

Y_i = Number of species i in community B

$$N_A = \sum X_i$$

$$N_B = \sum Y_i$$

$$S_A = \frac{\sum [X_i(X_i - 1)]}{N_A (N_A - 1)}$$

$$S_B = \frac{\sum [Y_i(Y_i - 1)]}{N_B (N_B - 1)}$$

Results and Discussion

Fuel loading results for all parks combined in 1999 (before burning) and 2000 (after burning), indicated a statistically significant reduction in one-hour fuels in burn plots in 2000; however, the actual difference was only 0.05 Mg ha^{-1}. This is not ecologically significant. There was also a statistically significant reduction in ten-hour fuels in the control plots, while there was no change in the burn plots (Table 1).

The only statistically significant difference in hundred- or thousand-hour fuels was an increase in thousand-hour fuels in control plots (Table 1). Larger fuels may have increased due to drought-stressed trees dying and falling.

For all parks combined, O_i and O_e horizons' combined weight decreased significantly (t = 5.182, $P < 0.001$) in the burn plots while it did not in the control plots (Table 2). The actual decrease in the burn plots was 0.98 Mg ha^{-1}. There was also a statistically significant decrease in depth of O_i and O_e combined in the burn plots (t = 2.074, $P < 0.05$), while there was a significant increase in the control plots (t = (6.641, $P < 0.001$)(Table 2).

Tiles recovered from the burns indicated weak burns at all parks, with Mission Tejas generally burning hotter than Tyler and Village Creek. Tiles showed no effect from the heat of the burns at the 61 cm (2 ft) level in any plot. One tile at Mission Tejas indicated 93°C at the 30 cm

Table 1. Mean fuel loads and paired *t*-test results for fuels in 1999 (pre-burn) and 2000 (post-burn) in Mission Tejas, Tyler and Village Creek State Parks combined.

Plot type	Measurement	One-hour	Ten-hour	Hundred-hour	Thousand-hour	Total
Burn	1999 fuel load (Mg ha^{-1})	0.29	1.78	1.81	1.63	5.53
(n = 60, df = 59)	2000 fuel load (Mg ha^{-1})	0.24	1.58	2.49	2.42	6.68
	Mean difference	0.05	0.19	-0.68	-0.79	-1.15
	SD	0.15	2.17	3.73	4.88	5.52
	t	2.453	0.687	-1.406	-1.254	-1.608
	Significance	0.017	0.495	0.165	0.215	0.113
Control	1999 fuel load (Mg ha^{-1})	0.31	2.25	1.74	2.55	6.84
(n = 36, df = 35)	2000 fuel load (Mg ha^{-1})	0.24	1.01	2.04	6.20	9.50
	Mean difference	0.07	1.23	-0.30	-3.64	-2.50
	SD	0.28	1.60	3.30	9.58	10.04
	t	1.518	4.610	-0.553	-2.282	-1.584
	Significance	0.138	<0.001	0.584	0.029	0.122

Table 2. Mean measurements in 1999 and 2000 and paired *t*-test results for O_i and O_e combined and O_a horizons in Mission Tejas, Tyler and Village Creek State Parks combined.

Plot depth type	Measurement	O_i and O_e weight (Mg ha^{-1})	O_i and O_e depth (cm)	O_a (cm)
Burn	1999	2.990	1.348	1.431
(n* = 60,	2000	2.015	1.203	1.353
df = 59)	Mean difference	0.976	0.145	0.077
	SD	1.409	0.542	0.550
	t	5.182	2.074	1.084
	Significance	<0.001	0.042	0.283
Control	1999	3.716	1.492	1.571
(n = 36,	2000	3.480	2.196	1.600
df = 35)	Mean difference	0.236	-0.703	-0.029
	SD	1.664	0.636	0.742
	t	0.850	-6.641	-0.234
	Significance	0.401	<0.001	0.817

* n = 56 for O_i and O_e weight in the burn plots, df = 55 for O_i and O_e weight in the burn plots.

(1 ft) level, while the others recorded no effect. At ground level, tiles indicated a range of intensities from 0°C to 538°C, with Mission Tejas averaging 293°C, Tyler averaging 149°C, and Village Creek averaging 45°C. At the subground level Mission Tejas averaged 197°C and Tyler

averaged 13°C, while tiles at Village Creek recorded no effect. This level of intensity could leave quite a bit of the O horizon and downed woody fuels unburned. After the fires, most surface fuels appeared charred but unconsumed.

It appears the burns did not fully reach the objective of reducing fuel loads. The only ecologically important effects were the decreases in weight and depth of the O_i and O_e horizons in the burn plots. The loss in weight from 1999 to 2000 was 0.98 Mg ha^{-1}, and the difference in depth between the burn and control plots in 2000 was 0.85 cm. These differences were possibly enough to affect the viability of seedlings or herbaceous plants.

VEGETATION

Mission Tejas State Historical Park.—With Axis 1 of the DCA graph representing decreasing time since prior disturbance, one plot was separated to the far right of the other plots in most vegetation classes because it had been burned in the past. There were no records of how long ago the burn occurred. The authors estimated it to be between five and ten years. The plot was very thick with loblolly saplings ranging between one and three inches in diameter.

In both 1999 and 2000, the overstory of Mission Tejas plots was dominated by shortleaf pine followed by sweetgum and loblolly pine. There was not a statistically significant change in number of dead standing overstory or sapling trees from 1999 to 2000. Saplings were dominated by shortleaf and loblolly pines, followed by white oak.

Morisita's similarity index showed relatively high similarity in composition of seedlings, 50 m shrub and herbaceous transects, shrub belts and herbaceous frames between burn and control plots in 1999 and 2000 (Table 3). They indicated little to no overall effect in these populations from the prescribed burn. Authors believe results would have indicated greater changes in composition had the burns been more severe.

In the seedlings class, loblolly pine, white oak and Southern red oak (*Quercus falcata* Michx.) were common. Sassafras (*Sassafras albidum* (Nutt.) Nees) was absent from the burn plots in 1999, while it was present to either a moderate or heavy degree in 2000.

Table 3. Morisita's similarity index results for plot comparisons at Mission Tejas, Tyler and Village Creek State Parks pre- (1999) and post-burn (2000).

Park	Plots compared	Seedlings	50 m shrub and herbaceous transects	Shrub belts	Herbaceous frames
Mission Tejas	Pre-burn: burn vs. control	0.93	0.61	0.76	0.69
	Post-burn: burn vs. control	0.89	0.94	0.84	0.85
	Burn plots: pre- vs. post-burn	1.00	0.95	0.88	0.99
	Controls: pre- vs. post-burn	0.97	0.88	0.88	1.20
Tyler	Pre-burn: burn vs. control	1.02	0.76	0.94	0.85
	Post-burn: burn vs. control	0.92	0.99	0.99	0.95
	Burn plots: pre- vs. post-burn	0.99	0.85	0.96	0.92
	Controls: pre- vs. post-burn	1.02	0.98	0.90	0.96
Village Creek	Pre-burn: burn vs. control	1.00	1.01	0.86	0.00
	Post-burn: burn vs. control	1.00	0.00	0.60	0.00
	Burn plots: pre- vs. post-burn	1.00	0.80	1.02	0.43
	Controls: pre- vs. post-burn	1.01	0.00	0.41	0.00

For the 50 m shrub and herbaceous transect, litter was more commonly intersected than all plant species combined. In the previously burned plot, the transect was dominated by a heavy ground cover of poison ivy, with little room for anything else. Smilax (*Smilax* sp.), Virginia creeper (*Parthenocissus quinquefolia* (L.) Planch.), poison ivy, muscadine grape (*Vitis rotundifolia* Michx.) and partridge-berry (*Mitchella repens* L.) were commonly intersected in the other plots.

The 0.5 m wide shrub belts in all plots at Mission Tejas were dominated by poison ivy, smilax and Virginia creeper, with moderate amounts of muscadine grape and American beautyberry. In the herbaceous classification, the only obvious change from 1999 to 2000 was the heavy presence of goldenrod (*Solidago* sp.) in two of the burn plots in 2000. Goldenrod is a common invader species after disturbance, and was not recorded at all in 1999.

This burn was part of the fuel reduction phase described in the burn plan (Robinson & Blair 1997). Killing or weakening understory shrubs and pine saplings was one goal of the fuel reduction phase. Results indicated no significant changes in overstory, sapling, seedling, shrub or herbaceous populations.

Tyler State Park.—The overstory of plots at Tyler State Park was characterized by shortleaf pine and post oak (*Quercus stellata* Wangenh.). There were no significant changes in dead standing overstory trees from 1999 to 2000.

When graphed in DCA, two plots were commonly placed on the right of the rest of the group. Axis 1 represented soil moisture, with decreasing soil moisture to the right of the graph. These two plots were higher in elevation and would have lower soil moisture than the others.

T-tests indicated a significant increase in percent of dead saplings in 2000 in the burn plots ($t = 3.004$, $P = 0.003$). In 1999, there were 7.9 percent dead saplings while there were 18.5 percent in 2000. The control plots indicated the opposite trend, although it was not significant statistically. Thus the increase in the burn plots was evidently due to the burn. Saplings were already suffering drought stress and the additional stress of the burn exterminated weaker individuals. Further *t*-tests indicated no significant differences in dbh or height class of saplings from 1999 to 2000, indicating that combined stresses affected saplings of all diameters and heights evenly.

Morisita's similarity index illustrated very high similarity between seedlings, 50 m shrub and herbaceous transects, shrub belts and herbaceous frames, from 1999 to 2000, even between burn and control plots (Table 3). In the seedlings class, sweetgum and sassafras were most common, followed by Southern red oak, winged elm (*Ulmus alata* Michx.), red maple, flowering dogwood and American elm. Litter was most often recorded in the 50 m shrub and herbaceous transects. In 2000, twinspan separated plots based on the presence of bare ground. No bare ground was recorded in 1999. The presence of it in 2000 could have been a result of the prescribed burn removing the O horizon.

There were some changes in shrub belt data from 1999 to 2000 in Tyler State Park. Muscadine grape, poison ivy and smilax were common. American beautyberry was absent in 1999, while there was a heavy presence of it in one plot in 2000 that had burned very hot, as evidenced by char height after the burn. Virginia creeper, which was heavily present in that plot in 1999, was absent in 2000. Longleaf uniola was common in the herbaceous frames.

The 10.6 percent increase in dead saplings appears to be the only significant difference in vegetation. The burn plan (Sparks 1999a) called for increasing herbaceous species, reducing brush species and enhancing species diversity and richness. None of these objectives were reached. The burn was not hot enough to accomplish these goals.

Village Creek State Park.—The overstory of Village Creek was characterized by longleaf pine, southern red oak, and sweetgum. Plots closest to the creek were separated from the others in twinspan because they contained river birch, commonly found in wet soils and streambanks, and Southern magnolia (*Magnolia grandiflora* L.), also common in moist valleys (Little 1980). They also contained lesser amounts of Southern red oak than did other plots, which is more commonly found in dry, sandy loams (Little 1980). When graphed, DCA Axis 1 represented increasing soil moisture in both years in most vegetation classes. *T*-tests indicated no significant changes in standing dead overstory trees.

In saplings, yaupon and redbay were dominant. *T*-tests indicated a significant increase in the number of dead saplings in the burn plots from 1999 to 2000, 12.6 to 19.6 percent, respectively (t = 2.286, P = 0.023). There was only a slight increase in the control plots, from 12.8 to 13.9 percent. This illustrated a cumulative effect within the burn plots of the drought and the burn combined. There were no significant differences in dbh and height class between 1999 and 2000, illustrating that combined impacts of fire and drought affected all sizes evenly.

Chinese tallowtree was becoming increasingly common in the sapling and seedling stages at Village Creek. It is a native species of China, which has been widely planted as an ornamental in the U.S., because of its vivid fall colors. Seedlings less than one foot tall were omnipresent in areas that were typically wet, but dry due to drought. Chinese tallowtree is hardy, common in sandy soils along streams and grows quickly into thickets (Little 1980). It has the potential to overtake natural vegetation in many areas of the park if left unmanaged.

Morisita's similarity index reflected nearly exact similarities in seedling composition between all control and burn plots in both years (Table 3). The burn appeared to have no effect on composition of seedlings. This was not surprising considering the wet condition of the fuels during the burn.

On the shrub and herbaceous transects, litter dominated intercepts on all plots. There were more species of vegetation, and vegetation occurred more often in 1999 than 2000. Although a burn could cause a reduction in shrub species, even herbaceous species, such as little bluestem and a carex sedge (*Carex joorii* Bailey) were also reduced. This is more indicative of drought effects than those of prescribed burning.

Morisita's similarity index indicated a high degree of similarity between burn and control plots in 1999 (Table 3). However, in 2000, every hit along transects within control plots contacted no vegetation, only litter. This resulted in 0.00 similarity between burns and controls in 2000, and controls in 1999 and 2000. The lack of brush and herbaceous vegetation in the control plots was due to the sustained drought. Village Creek is the northern boundary of the park. The creek often floods in the winter and spring and cypress swamps are present near both the control and the burn units. Because of the drought, the yearly flooding had not occurred in 1999 or 2000; the swamps were dry, and vegetation severely affected.

There were also decreases in the total number of shrub belt species and the numbers recorded within species from 1999 to 2000. The drought appeared to play an important factor from the first year to the next. Some species increased in certain plots while decreasing in other plots, with other species exhibiting opposite responses in those same plots. This is indicative of too few resources. The species with the firmer hold on an area won out.

Morisita's index also indicated a cumulative effect of the drought and the burn in Village Creek's shrub belt composition (Table 3). Oddly, the highest rating (1.02) was received by the similarity in the burn plots between 1999 and 2000, indicating no effect on composition by the burn.

The effect of prolonged drought was also evident in the herbaceous frames. In both years, the majority of herbaceous frames were empty in all plots. Morisita's similarity index resulted in all comparisons receiving either 0.00 or a low rating (Table 3). This was due to the total lack of herbaceous vegetation in many of the frames in 2000.

At Village Creek the only significant effect of the burn on vegetation was in the percent of dead saplings. The increase, seven percent, in the burn plots was six percent greater than in the control plots. The objectives of encouraging longleaf seedlings, herbaceous species, and increasing species richness and diversity were not met.

CONCLUSIONS

Compared to forests with long-interval, high-severity fire regimes, characterized by stand replacing fires, forests with low- to moderate-severity regimes, characterized by low-intensity surface fires may experience greater adverse effects from high intensity wildfires because they are not adapted to them. Generally, these forests adapted to low-intensity surface fires are more adversely affected by fire suppression and other human influences following European settlement. Active fire seasons occur at more frequent intervals than in long-interval types, due to longer fire seasons, higher average temperatures, and exposure to more potential ignitions during a given fire season. They have missed more fire cycles than longer interval fire regimes, and are generally in greater need of wildfire hazard reduction and restoration of ecological integrity. Wildfires in these areas not only cause more detrimental ecological effects, but they pose great risks to firefighters and property.

It is anticipated with most prescribed burning programs, that the resulting post-fire landscape will have significantly reduced fuel loads and reduced risks of detrimental wildfires. If the post-fire landscapes are also attractive to those who influence policy, positive social benefits can be anticipated as well.

The primary goal of each of these burns was to reintroduce or establish prescribed burning in these parks to further this mission. That objective was met. Park staffs were introduced to the duties, dangers and special considerations necessary with conducting prescribed burns. Each time they are performed by park staff, burns should become less stressful and more efficient.

This short-term project has determined that future burns must be more intense to meet the fuel loads and vegetation goals outlined in the burn plans. This will require a great deal of cooperation and preparedness from park staff. The window of opportunity to conduct a burn with the desired outcomes may be quite small in any given year. Fuel moisture, wind direction and speed, ambient temperature and capable staff availability must all be ideal to conduct a burn. Once the natural resources coordinator (NRC) has identified an area to be burned it is the responsibility of the park staff to prepare and maintain it in a ready condition.

Initially, dormant season burns should be conducted every two years to reduce fuel loads sufficiently to initiate early to late spring burns. This will require at least two more cool season burns of greater intensity than the burns presently studied. Spring burns occurring every three years will establish a vegetation restoration phase. After a diverse herbaceous layer and open understory have been established, a maintenance phase of burning every five to eight years, depending on desired vegetation, can begin (DellaSala & Frost 2001; Manley et al. 2001).

In years with inadequate prescribed fire windows due to extreme drought or flooding, prescribed burning should not be undertaken. It is too expensive and inefficient to extract employees from their normal duties, and use expensive tools, trucks and ATVs to accomplish so little ecologically. However, TPWD personnel must be willing to take risks based on the best available knowledge. Increasingly, scientific information points to the necessity of fire in maintaining sustainable, healthy forests in the Southeast. Being too cautious could be just as detrimental to the forest as an escaped prescribed fire. The risks of damage from wildfire, disease, insects and overcrowding are increased when prescribed fire is put off another year in hopes of better burning conditions. Fire exclusion will ultimately result in a shift from a nonlethal understory fire regime to a stand-replacement regime accompanied by changes in composition and diversity.

In Texas, county judges are responsible for issuing burn bans, even those with little ecological experience on which to rely. Ideally, a relationship should be fostered between the NRC and county judges issuing the bans. Judges are accustomed to making decisions based on facts and the good of the whole, rather than emotion. They should be capable of understanding the importance of fire on the landscape and the precautions taken to keep prescribed burns contained. These parks, particularly Village Creek, would have burned naturally during very dry periods. To be forced to adhere to burn bans during these times greatly reduces the restorative powers of prescribed burning. The judges have the authority to allow TPWD to burn for ecological reasons during a burn ban.

In this instance, had TPWD not been bound by the burn bans, burns could have been conducted when fuels were more dry. The failure to reach the objective of reducing fuels in the parks was a direct result of waiting until after a rain event occurred to burn.

Long-term interdisciplinary research projects are necessary to quantify the ecological effects, and economic and social trade-offs of prescribed burning. Only through long-term research may it be determined which natural fire functions can be emulated with prescribed burning, which are irreplaceable, and the implications for management.

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